Chapter 5
Overview of Sewer Cleaning
Flushing Systems and CSO Tank Cleaning Technology

The deposition of sewage solids during dry weather in combined sewers has long been recognized as a major contributor to "first-flush" phenomena. Another manifestation of first-flush, in addition to the scouring of materials already deposited in the lines, is the first flush of loose solid particles on the urban ground surface that are transported into the sewerage system and not trapped by catch basins or inlets. These particulates may settle out in the system and be scoured and resuspended during wet periods. Such materials also create first flush loading from storm drainage systems. Deposition of heavy solids is also a problem in separate sanitary systems.

One of the underlying reasons for considerable sewage solids deposition in combined sewers is the hydraulic design. Combined sewers are sized to convey many times the anticipated peak dry weather sewage flow. Combined sewer laterals can carry up to 1000 times the expected background sewage flow. Ratios of peak to average dry weather flow usually range from 2 to 10 for interceptor sewers. The oversized combined sewer pipes possess substantial sedimentation potential during dry weather periods. Dry weather flow velocities are typically inadequate to maintain settleable solids in suspension which tend to accumulate in the pipes. During rainstorms, the accumulated solids can re-suspend and overflow to receiving waters.

Generally if sediments are left to accumulate in pipes, hydraulic restrictions can result in blockages in flowline discontinuities. Otherwise, the bed level reaches an equilibrium level. A number of conventional cleaning techniques are described below, followed by a discussion of various manual and automated flushing methods.

Over the past 50 years nearly 15,000 CSO tanks have been constructed world-wide. In the US there are approximately 300 facilities mostly off line at the end of collection systems. The balance are mostly in Europe with nearly 14,000 constructed in Germany. Tank cleaning methods are reviewed.

Conventional Sewer Cleaning Techniques

Conventional sewer cleaning techniques include rodding, balling, flushing, poly pigs and bucket machines. These methods are used to clear blockages once they have formed, but also serve as preventative maintenance tools to minimize future problems. With the exception of flushing these methods are generally used in a "reactive" mode to prevent or clear up hydraulic restrictions. As a control concept, flushing of sewers is viewed as a means to reduce hydraulic restriction problems as well as a pollution prevention approach.

Power Rodding

Power rodding includes an engine and drive unit, steel rods and a variety of cleaning and driving units. The power equipment applies torque to the rod as it is pushed through the line, rotating the cleaning device attached to the lead end. Power rodders can be used for routine preventative maintenance, cutting roots and breaking up grease deposits. Power rodders are efficient in lines up to 0.30 meters (12 inches).

Balling

Balling is a hydraulic cleaning method in which the pressure of a water head creates high velocity water flow around an inflated rubber cleaning ball. The ball has an outside spiral thread and swivel connection that causes it to spin, resulting in a scrubbing action of the water along the pipe. Balls remove settled grit and grease buildup inside the line. This technique is useful for sewers up to 0.60 meters (24 inches).

Jetting
Jetting is a hydraulic cleaning method that removes grease buildup and debris by directing high velocities of water against the pipe walls at various angles. The basic jetting machine equipment is usually mounted on a truck or trailer. It consists of water supply tank of at least 3.8 cubic meters (1,000 gallons), a high pressure water pump, an auxiliary engine, a powered drum reel holding at least 152 meters (500 feet) of one inch hose on a reel having speed and direction controls and a variety of nozzles. Jetting is efficient for routine cleaning of small diameter, low flow sewers.

Pigging
Poly pigs, kites, and bags are used in a similar manner as balls. The rigid rims of bags and kites cause the scouring action. Water pressure moves these devices against the tension of restraining lines. The shape of the devices creates a forward jet of water. The poly pig is used for large sanitary sewers and is not restrained by a line, but moves through the pipe segment with water pressure buildup behind it.

Power Bucket
The power bucket machine is a mechanical cleaning device effective in partially removing large deposits of silt, sand, gravel, and grit. These machines are used mainly to remove debris from a break or an accumulation that cannot be cleared by hydraulic methods. In cases where the line is so completely plugged that a cable cannot be threaded between manholes, the bucket machine cannot be used. The bucket machine is usually trailer or truck mounted and consists mainly a cable storage drum coupled with an engine with controllable drive train, up to 300 meters (1000 feet) of 1.3 centimeter (1/2-inch) steel cable and various sized buckets and tools ranging up to in diameter. The cable drum and engine are mounted on a framework that includes a 0.9 meter (36 inch) vertical A-frame high enough to permit lifting the cleaning bucket above ground level. Typically two machines of same design are required. One machine at the upstream manhole is used to thread the cable from manhole to manhole. The other machine is used at the downstream manhole has a small swing boom or arm attached to the top of the A-frame for emptying buckets. The bucket is cylindrical. The bottom of the bucket has two opposing hinged jaws. When the bucket is plugged through the material obstructing the line, these jaws are open and dig into and scrape off the material and fill the bucket. When the bucket is pulled in the reverse direction, the jaws are forced closed by a slide action. Any material in the bucket is retained as the bucket is pulled out through the manhole.

Silt Traps
Silt traps (or grit sumps) have successfully been used to collect sewer sediments at convenient locations within the system with the traps being periodically emptied as part of a planned maintenance program. The design and operational performance of two experimental rectangular (plan) shaped silt traps in French sewer systems was reported (Bertrand-Krajewsk, Madiec, and Moine, 1996). Information on design procedures and methodology for silt traps is scarce.

Sewer Flushing
Flushing of sewers has been a concern dating back to the Romans. Ogden (1892) described early historical efforts for cleaning sewers in Syracuse, New York at the turn of the century. The concept of sewer flushing is to induce an unsteady wave by either rapidly adding external water or creating a "dambreak" effect by quick opening a restraining gate. This aim is to re-suspend, scour and transport deposited pollutants to the sewage treatment facility during dry weather and/or to displace solids deposited in the upper reaches of large collection systems closer to the system outlet. The control idea is either to reduce depositing pollutants that may be resuspended and overflow during wet events and/or to decrease the time of concentration of the solids transport within the collection system. During wet weather events these accumulated loads may then be more quickly displaced to the treatment headworks before overflows occur or be more efficiently captured by wet weather first flush capture storage facilities.

Recently, Gatke and Borcherding (1996) investigated the effectiveness of long distance flushing of a 4.5 meter (14.8 feet) diameter CSO tunnel 360 meters (1180 feet) in length using a physical (1:24 scale) hydraulic model coupled with numerical simulation techniques. The work showed that a reservoir 15.5 meters (50.8 feet) high with about a release volume of 360 cubic meters (95,100 gallons) would be adequate for cleansing sediments.

Manual flushing methods usually involve discharge from a fire hydrant or quick opening valve from tank truck to introduce a heavy flow of water into the line at a manhole. Flushing removes floatables and some sand and grit, but is not very effective for removing heavy solids. In recent years, automated flushing equipment has emerged in France and Germany.

Hydrass ®

The Hydrass flushing system developed in France, and shown in Figure 5-1, is comprised of a balanced hinged gate with the same shape as the cross section as the sewer. At low flows the self-weight of the gate holds the gate in the vertical position and the sewer flow builds up behind the gate. The depth of flow continues to build up behind the gate until the force created by the retained water becomes sufficient to tilt the gate. As the gate pivots about the hinge to a near horizontal position, the sewer flow is released and this creates a flush wave which travels downstream and subsequently cleans any deposited sediment from the invert of the sewer. The gate then returns to the vertical position and the cyclic process is repeated, thus maintaining the sewer free of sediment. Gates are positioned in series at intervals dictated by the nature, magnitude and location of the sedimentation problem. Chebbo, Laplace, Bachoc, Sanchez and LeGuennec (1995) reported the effective operation of the Hydrass system. This system has been installed on a segment of the Marseilles Number 13 trunk. A 100 meter (328 feet) stretch required about 700 flushes to clean an initial deposit of about 100 millimeters (4 inches). Flushing frequency can be reduced if the upstream head can be increased, i.e., the number of flushes with a 0.5 meter (1.6 feet) head is 24 times that required for a 1.5 meter (4.9 feet) head.

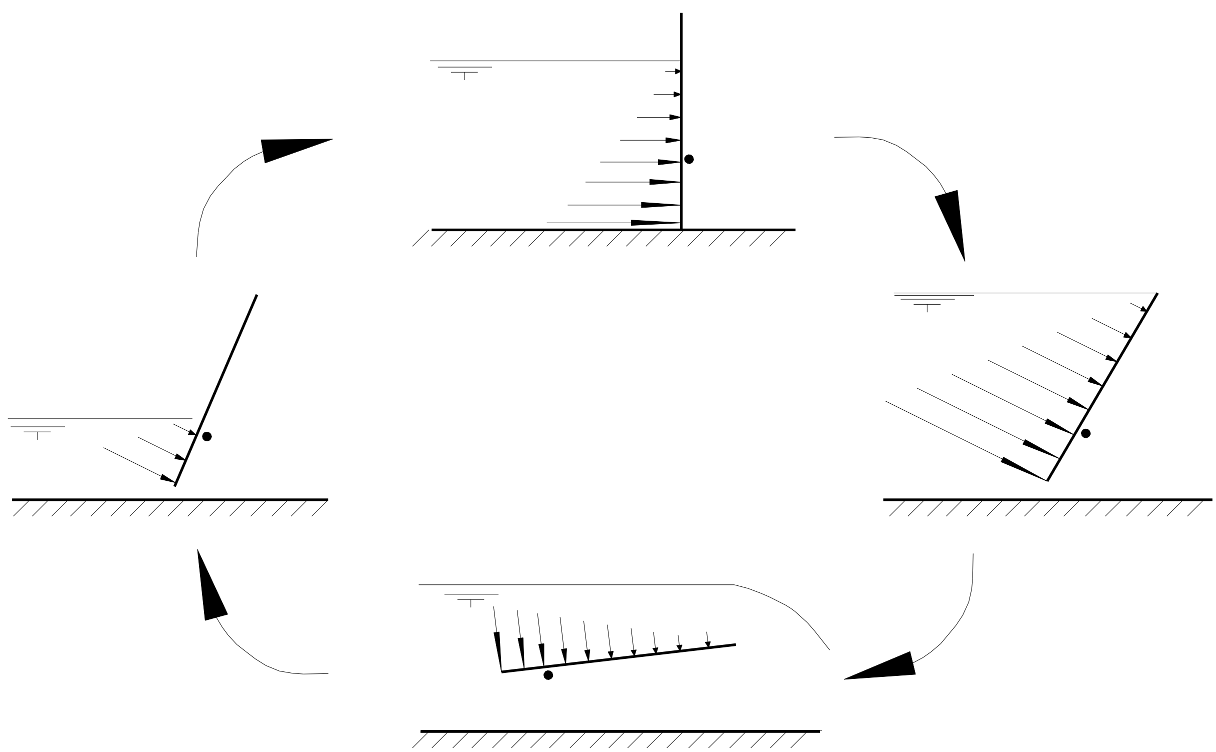


Diagram showing how the HYDRASS gate operates

Figure 5-1. Hydrass®

Hydroself®

In recent years pollution caused by CSO has become a serious environmental concern. Over 13,000 CSO tanks have been constructed with over 500 being in-line pipe storage tanks 1.8 to 2.1 meter (6 to 7 feet) diameter with lengths 125 to 180 meters (400 to 600 feet). Discharge throttles control the outlet discharge to about twice average dry weather flow plus infiltration. Many different methods for cleaning these pipes were tried over the years. The most popular has been the HYDROSELF® system developed by Steinhardt Wassertechnik, Taunusstein about 11 years ago.

The HYDROSELF® system is a simple method that uses a wash water storage area and hydraulically operated flap gates to create a cleaning wave to scour inverts of sewers. This system consists of a hydraulically operated flap gate, a flush water storage area created by the erection of a concrete wall section, a float or pump to supply hydraulic pressure and valves controlled by either a float system or an electronic control panel. The water level in the sewer is used to activate the release and/or closure of the gate using a permanently sealed float controlled hydraulic system. The flushing system is designed to operate automatically whenever the in-system water level reached a pre-determined level, thereby releasing the gate and causing a "dambreak" flushing wave to occur. Activation by remote control is also possible. This technology does not require an outside water supply, can be easily retrofitted in existing installations with a minimal loss of storage space, and may operate without any external energy source. The system consists of a hydraulically operated flap gate, a flush water storage area created by the erection of a concrete wall section, a float or pump to supply hydraulic pressure and valves controlled by either a float system or an electronic control panel. See Figure 5-2. The actual arrangement for a given installation is site dependent. The flushing length, slope and width determine the flush water volume needed for an effective single flush of the system.

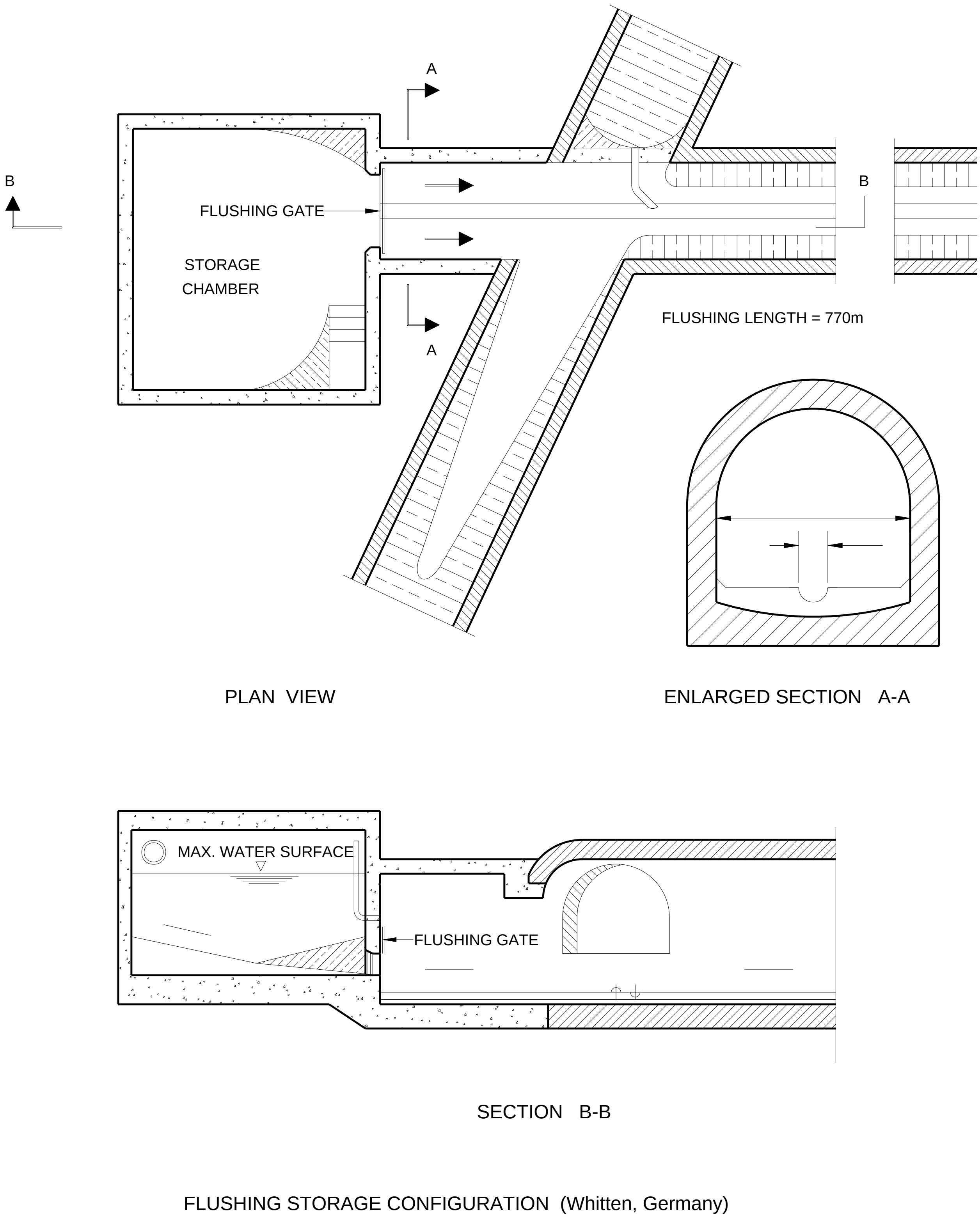


Figure 5-2. Flushing Gate

The HYDROSELF® system has been used to clean settled debris in sewers, interceptors, tunnels, retention and detention tanks in Germany and Switzerland. This technology was first used in 1986 for cleaning a tank in Bad Marienberg (a small town with a population less than 10,000 people, about 100 kilometers northeast of Frankfurt). In that same year the first two pipe storage projects using the flushing gate technology were implemented. This system has been used extensively in Europe with 284 installations with over 600 units in operation. Approximately 37 percent of the projects are designed to flush sewers, interceptors and tunnels ranging from 0.25 meters to 4.3 meters (0.8 to 14 feet) in diameter and flushing lengths of up to 340 meters (1100 feet) for large diameter pipes and up to 1000 meters (3300 feet) for small diameter pipes. The balance of flushing gate installations is for cleaning sediments from CSO tanks. The largest project in Paris, France cleans an underground 120,000 cubic meter (31.6 million gallons) tank beneath a soccer field using 43 flushing gates.

For large diameter sewers greater than 2 meters (78 inches) the flushing system may be installed in the sewer pipe itself. The required storage volume for the flush water is created by erecting two walls in the sewer pipe to form a flush water storage area in between the two walls. For the area to remain free of debris, a reasonable floor slope (5 to 20 percent) must be provided in the storage area. The requirements for the storage area slope will determine, in most instances, the maximum flushing length possible for a single flush gate. Should the actual flushing length be longer than this value, then additional flushing gates must be installed to operate in series with the first one. In order to increase the maximum flushing length it is also possible to build additional flush water storage area by creating a rectangular chamber in-line or adjacent to the sewer line itself.

BIOGEST® Vacuum Flushing System

A variation of the HYDROSELF® is the BIOGEST®, which is a system comprised of a concrete storage vault and a vacuum pump system to create a cleaning wave to scour the inverts of sewers. The system consists of a flush water storage area, diaphragm valve, vacuum pump, level switches, and a control panel for automatic operation of the system. The water level in the sewer is used to activate the vacuum pump. The vacuum pump evacuates the air volume from the flush chamber and as the air is evacuated the water is drawn in from the sewer and rises in the chamber. The vacuum pumps shuts off when a predetermined level in the flushing vault is reached. A second level sensor detects the water level in the sewer and activates the flush wave. The flush wave is initiated by opening the diaphragm valve above the flush chamber and subsequently releasing the vacuum and vault contents.

Storage Tank Cleaning Alternatives

Introduction

There are many ways to clean debris and sediment in storage tanks. The most simple and primitive cleaning methods include hand labor with shovels, brooms and high-pressure hoses for small tanks, or small bulldozers and clamshells for larger tanks. The most modern and sophisticated technologies include tipping flushers and flushing gates and are often self-actuating.

Originally tanks were cleaned utilizing automated cleaning options such as traveling bridges, fixed spray headers and nozzles and submerged mixers. These types of automated cleaning options are primary cleaning operations. Ineffective primary cleaning options often required manual cleaning such as water cannons or high pressure hoses to be an integral part of the overall tank cleaning procedure. Manual cleaning procedures such as water cannons or high pressure hoses are secondary cleaning options. However, as technology and personnel confidence has evolved many tanks now incorporate only a primary source of cleaning because it operates efficiently (i.e., tipping flushers and flush gates). From a functional perspective a primary method of cleaning is considered highly effective if little "mop-up" cleaning is required. Often the "mop-up" incorporates visual tank inspection and periodic washdown of debris in tank corners and other locations that were bypassed by the primary flushing operation. Some flushing methods are nearly self sufficient and require little or no personnel interaction other than starting the system (tipping flushers and flush gates), while others need operators to guide the cleaning operation (water cannons and traveling bridge). In Germany, over 13,000 CSO tanks (mostly rectangular) have been constructed, and two premier technologies have evolved: tipping flushers and flush gates.

It is important to note that the method of flushing also impacts the configuration of the tank's bottom. Bottom sloping enhances the removal of settled solids during tank draining and cleaning operations. If header nozzle systems are used for washdown the tank is typically configured with a center trough, traversing the length of the tank, and sloping towards the effluent end and the tank bottom slopes from the side walls to the trough at 3-10 percent. Where tipping flushers or "flush" gates are used the channel bottom slopes at 2-3 percent from the flusher end toward a large, wide collecting trough at the opposite end of the tank.

The floor design should consider the maximum admissible slopes to ensure high scouring velocities during drainage and cleaning operations, while optimizing the depth, area and overall storage tank volume. Tank bottom design should incorporate input from the flushing equipment supplier to assure proper operation and sizing. The design of the end trough for tipping flusher and flush gate installation is as critical as the tank design and must be sufficiently wide in its cross section to prevent "splash back" from occurring. Peculiarities in terms of special side sloping are discussed with each method.

There are five practical methods that are feasible from an operational standpoint for cleaning the accumulated sludge and debris in storage tanks. Two of the methods are similar and include wash down nozzles attached to a moveable bridge and fixed headers and jetting nozzles. The three remaining cleaning methods are mixers, tipping flushers and flushing gates.

Primary Flushing Systems

Traveling Bridge

There are three general types of traveling bridges that have been used to clean CSO storage tanks. Discussions specific to each of the three are provided below.

Traveling Bridge - Scraper

The Ruhrverbund Sewage Authority in Essen, Germany maintains 93 WWTP's, several hundred CSO tanks and a number of multi-purpose water resource reservoirs, water treatment plants and groundwater recharge systems. In the last 50 years the Ruhrverbund has tried and discarded many types of cleaning equipment and dozens of different types of channels on the tank floor to increase tractive shear on draindown. One fairly common method developed 10-15 years ago (but not having any other installations since) was a traveling bridge with a hard rubber blade or "squeegee" that moved sludge on the tank bottom to a side channel. From the side channel sludge was pumped vertically to a channel trough at top of the tank wall, then drained to a local sewer. Montgomery Watson personnel visited Germany in April 1994 to inspect various tank cleaning systems. Visual inspection of the traveling bridge scraper operation at several facilities showed poor scraper performance (it was impossible to get the floor cleaned and odors were a problem). However, the side channel sludge pickup system worked satisfactorily.

Traveling Bridge - Suction Pickup

The Ruhrverbund maintains about 6 tanks with traveling bridges having pumped suction manifolds that "suck" up sludge to a discharge channel at the top of the tanks and ultimately drain to WWTP's. Such arrangements are commonly used in secondary clarifiers in Europe and the Ruhrverbund tried this idea on CSO tank sludge. Visual inspection of the latest constructed facility indicated that small "wind rows" of sludge remained, and additional, extensive secondary washdown was necessary to supplement the bridge performance.

Traveling Bridge with Washdown Nozzles

There are only two known traveling bridges with washdown nozzles installed in the United States, Worcester, Massachusetts and Spring Creek, New York. The Worcester tank will be discussed for the purpose of this report.

Figure 5-3(a) depicts the traveling bridge arrangement installed at this facility. The storage tank has a volume of 5700 cubic meters (1.5 million gallons) with two cells 57 meters by 15.3 meters by 5.8 meters (187 feet by 50 feet and 19 feet) deep. The slope from the sidewalls to the center of the cell is 4 percent and a sloped sump is located at the center of each cell. Each cell is equipped with a moveable bridge which is operated by a two-speed chain drive at 1.5 and 2.5 meters (5 and 8 feet) per minute. The bridge is equipped with a traveling pump (95 liters/second, 1500 gpm), a ductile iron pipe system with 52 spray nozzles spaced 0.3 meters (1 foot) on center for the horizontal bottom and 3 nozzles on each of the vertical pipe assemblies, and a water cannon. On the outside of each basin is a 1.35 meter (4.5 feet) wide water trough that runs the entire length of the tank, and supplies water for the washdown system. Two passes are generally sufficient to clean the tank. Visual inspection indicates that the side vertical nozzles are not required to clean the tank walls because nothing adheres to them.

This system has been in operation for five years and has performed very efficiently although it requires significant operation and maintenance and is costly. One advantage of this system is that the primary and secondary modes of cleaning are located in a central location, the bridge. The disadvantages of this system include:

- Significant water consumption during the cleaning operation;
- The traveling bridge mechanism requires frequent maintenance;
- The initial installation requires extensive alignment of the bridge mechanism;
- Many mechanical components;
- The system requires a secondary mode of cleaning (i.e., water cannons);
- High structural costs associated with the water supply reservoir for each basin; and
- Since the traveling bridge is located above the high water elevation in the storage tank, it must be used with an open tank concept.

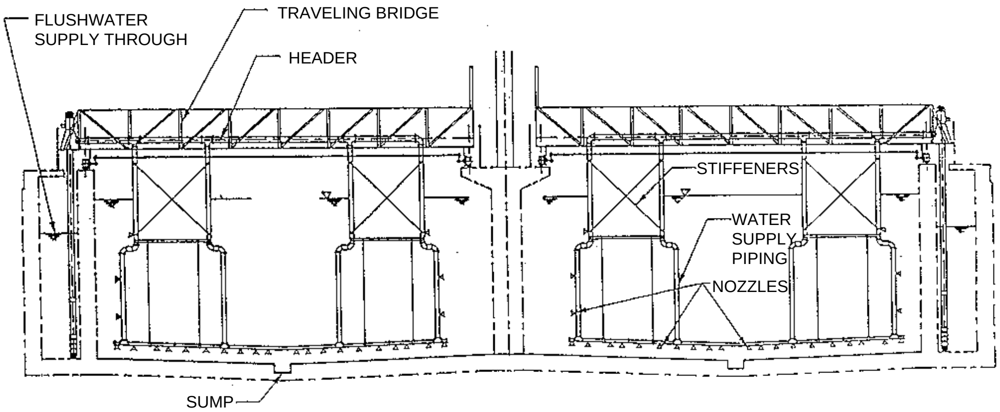
Mechanical Mixers and Submerged Jets

The basic principle involved with this technique is different from washdown systems that aim to clean sediments from empty tanks. Mechanical mixers and water jets operate on the premise of resuspending settled debris before drawdown begins and maintaining all materials in suspension until the tank is completely drained. Re-suspension of solids requires an introduction of energy to create necessary turbulence. This method is very popular for small tanks in central Germany. The actual placement of the mixers requires considerable adjustment to optimize mixing and establish proper mixing currents and flow directions

Estimates of required mixing energy could be assumed using criteria established for aerobic digesters depending on inorganic solids concentration. As the water depth in a tank decreases during the drawdown procedure, the mixing power must increase proportionally to properly maintain solids suspension.

Although capital cost data is not available for installations of this type, it is clear that this system requires a considerable amount of energy in addition to equipment and operational costs similar to those for header and nozzle systems. A serious disadvantage of this system is the requirement to manually clean the residual inorganic solids on the tank floor following draindown, consequently requiring extensive secondary cleaning operations. Since a secondary cleaning operation must be utilized in conjunction with this technology, an open tank layout must be employed. Advantages of this system are that the captured solids are more uniformly returned to WWTP via the pumpback operation and that little additional water is used.

This technology is most appropriate for circular tanks because circulation can easily be accomplished with few dead spots. Designers are constantly experimenting with fillets and baffles in rectangular tanks because flow currents are extremely complicated to predict when using mixers. A submerged jet is depicted in Figure 5-3(b).



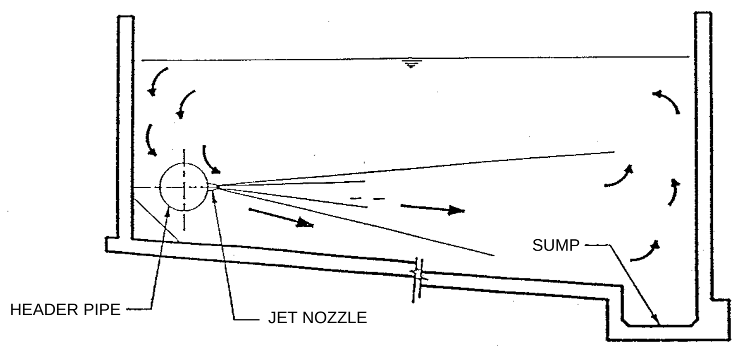


Figure 5-3 (a) Traveling Bridge (Adapted City of Worcester, 1998)

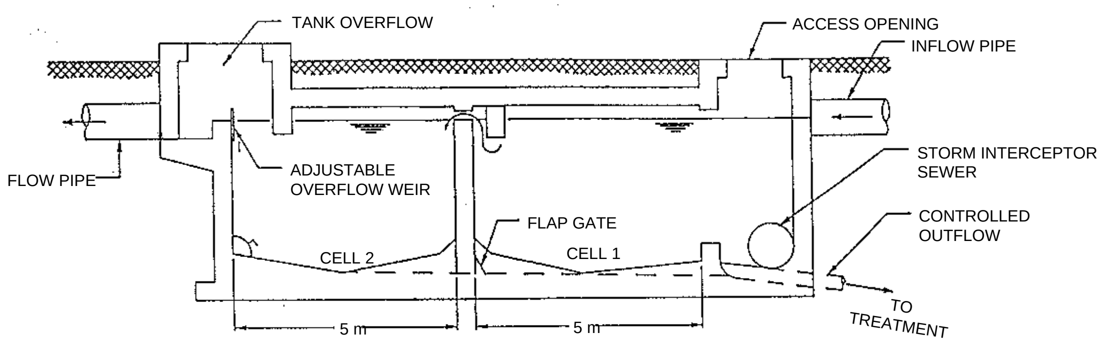
(b) Submerged Jet

Fixed Spray Nozzles and Headers

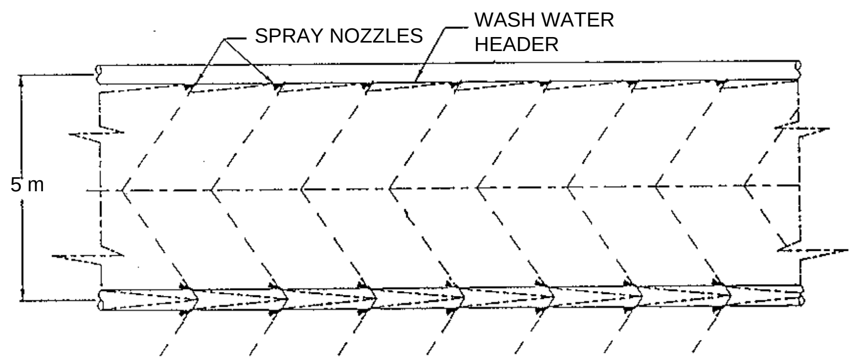
Fixed spray nozzle and header systems are generally comprised of an extensive piping network with multiple valves, booster pumps and controls and a washdown wet well. The spray headers and nozzles are generally suspended inside the tanks. This alternative requires secondary cleaning operations, typically with water cannons, because of the inefficiency of the spray nozzles to clean the entire tank. A dedicated secondary cleaning system must be used in conjunction with this technology, and thereby necessitates an open tank concept be incorporated. The tank bottom required for this system slopes steeply (approximately 10 percent) from the sidewalls to a center trough, and the center trough slopes at 2 - 3 percent toward an effluent trough. Disadvantages associated with this alternative include:

- Significant water consumption during the cleaning operation;
- The system requires a secondary mode of cleaning (i.e., water cannons);
- Floatables get caught on the header system; and
- Excessive sediment and debris can accumulate in areas where the nozzles do not reach.

Experience has shown that fixed spray headers and nozzles have been somewhat effective at some installations but do have some limitations. The Toronto Easterly Beaches Phase 1 tank (3800 cubic meters, 1 million gallons) could not be washed all at once because the washdown system demand, both pressure and flowrate, depleted the city supply system. Ultimately the tank was washed in quadrants to relieve the strain on the city system. The Saginaw, Michigan Weiss Street Facility 36,100 cubic meters (9.5 million gallons) tank had 1830 meters (6000 feet) of 0.41 meter (16 inch) diameter pipe with nozzles spaced 1.2 meters (4 feet) on-center and 24 water cannons to perform the cleaning operations. Since this system was installed four other tanks have been built by the city and all have incorporated tipping flushers as the primary cleaning technology. The cost and disadvantages associated with this alternative do not make it a feasible option for this installation. A typical spray header and nozzle arrangement is depicted in Figure 5-4.



A - TANK CROSSECTION



B - CLEANING NOZZLE ARRANGEMENT

Figure 5-4. Fixed Spray Header and Nozzle Arrangement

Tipping Flushers

Tipping flushers (TF) systems have been used in North America for three years (about 15 tanks with flushers in the US, with most located in Michigan area), and have been operational in Germany and Switzerland for over 9 years. Tipping flushers are extremely effective for subsequent cleansing of debris from the floors of all types of urban runoff tanks. These devices were initially developed in Switzerland.

The system generally include filling pipes and valves, a pumping system and wet well (where restricted by the site conditions), and the tipping flusher vessels. The TF is a cylindrical stainless steel vessel that is ideally suspended above the maximum water level on the back wall of the storage tank. The units can be filled with river water; ground water or potable water, but require a filling system consisting of 5 to 7.6 centimeters (2 to 3 inches) headers with appropriate controls. Just prior to overtopping the vessel with water, the center of gravity shifts and causes the unit to rotate and discharge its contents down the back wall of the tank. A curved fillet at the intersection of the wall and tank floor redirects the flushwater (with minimum energy loss) horizontally across the floor of the tank. The fillet size depends on the size of the flusher. The flushing force removes the sedimented debris from the tank floor and transports it to a collection sump located at the opposite end of the tank.

The experience with US TF systems to date indicates that dedicated secondary cleaning operations, using concurrently operated water cannons or high pressure hoses, are not needed. If the first flush of the basin does not remove all of the sediment, the basin can be re-flushed or "mopped-up" by fire hoses. In Germany and in Switzerland, tank sidewalls are generally hand trowelled to a very smooth finish to prevent buildup from occurring, and consequently don't require frequent washdown. "Mop-up" cleaning of the influent and washdown channels has been done utilizing small tipping flushers in large German tanks and in Saginaw, Michigan. See Figure 5-5 for an example of a tipping flusher installation.

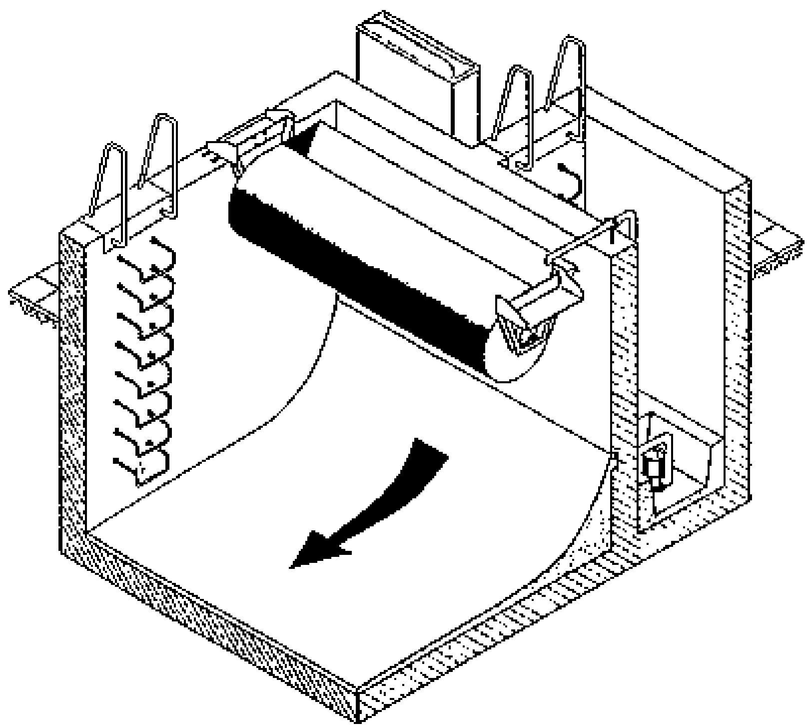


Figure 5-5. Tipping Flusher (adapted from UFT, 1998)

Flushing Gates

The flushing gate was originally developed in Germany (1985) as a method for flushing sediments in pipe segments (in-line storage or troublesome flat trunk and interceptor sewers), and has evolved for use in CSO tanks. As described earlier in this chapter, flushing gates have been used as the means to flush and cleanse deposits and debris from CSO tanks in about 350 German installations. In concept this scheme is depicted in Figure 5-6 and 5-7 from a recent design in Cincinnati, Ohio.

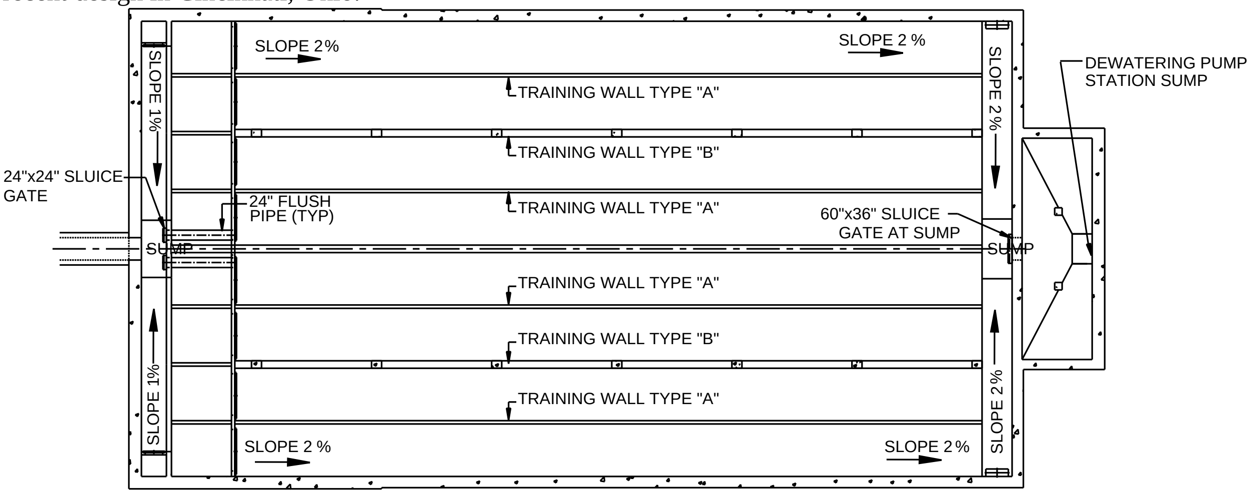


Figure 5-6. Plan View, Clough Creek CSO Treatment Facility, Cincinnati, Ohio

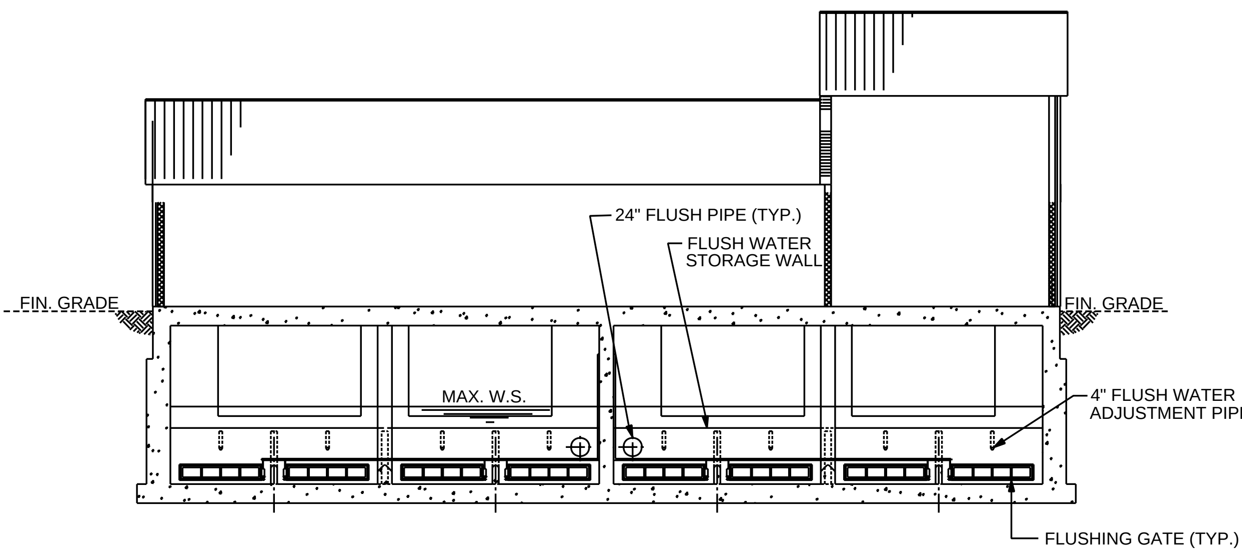


Figure 5-7. Section View, Clough Creek CSO Treatment Facility, Cincinnati, Ohio

The system is comprised of two basic elements, a gate and a closed circuit hydraulic actuation system utilizing a float control mechanism. A low-level wall is constructed across the short axis of the influent end of the tank approximately 1.5 to 2 meters (5 to 6.5 feet) high. The wall is located on the influent end of the tank to guarantee filling the space behind the wall prior to filling the rest of the tank. The instantaneous opening of a stainless steel gate that is mounted on the face of the wall activates the system. The release of the gate creates a "dam break" scenario, which generates a high velocity flush wave (generally trying to maintain a velocity in excess of 1.8 meters/second (6 feet/second). Normally the width of the flushing gate is approximately 0.7 the effective flushing lane width. The volume retained behind the wall required for proper cleaning is a function of flushing length and floor slope. The "nominal" design volume can be adjusted by changing the height of a level standpipe on the backside of wall. The hydraulic system can also be connected to central control system (on or off-site) with auto or manual override.

These systems have tank floors that slope from the flush gate location to the collection trough at 1 – 3 percent. The flush gates require training walls on the tank bottom that are about 0.4 to 0.5 meters (15 inches to 18 inches) high, and run the full length of the tank to control the flow direction of the wave. All walls parallel to the path of flushing flow should be perpendicular to the tank bottom, with no fillets, to ensure the lower wall edges are cleaned.

In function, this technology is similar in concept to tipping flushers. One main difference between the two technologies is that the tipping flushers are suspended above the tank floor and flush down sidewall, thereby taking advantage of the energy conversion from potential to kinetic. In practice, this means that the flushing gate needs about 20 percent more flushing volume than tipping flushers for comparable tank floor slope and tank lengths. However, since the flush volume consists of stored CSO, there is no additional cost associated with this volume. The experience with flush gate systems to date indicates that dedicated concurrent secondary cleaning operations, using water cannons or high pressure hoses, are not needed. If the flush of the basin using tank contents does not remove all of the sediment, the basin can either be re-flushed (requiring and external water source for filling), or "mopped-up" using fire hoses. To date flushing basins with tank contents has not required mop-up in German tanks. The largest length flushed with flushing gates is 90 meters (295 feet) while flushing lengths of 70 meters (230 feet) are fairly common.

Secondary Flushing Systems

Water Cannons

Water cannons are typically used to washdown corners, areas around piping, and other hard to reach places. They are typically used in conjunction with spray header systems (both fixed and traveling bridge) and mechanical mixers and submerged jets. These systems require extensive piping and valve networks, booster pumps, a supply wet well and are strictly operated manually. The use of water cannons requires an open storage tank configuration.

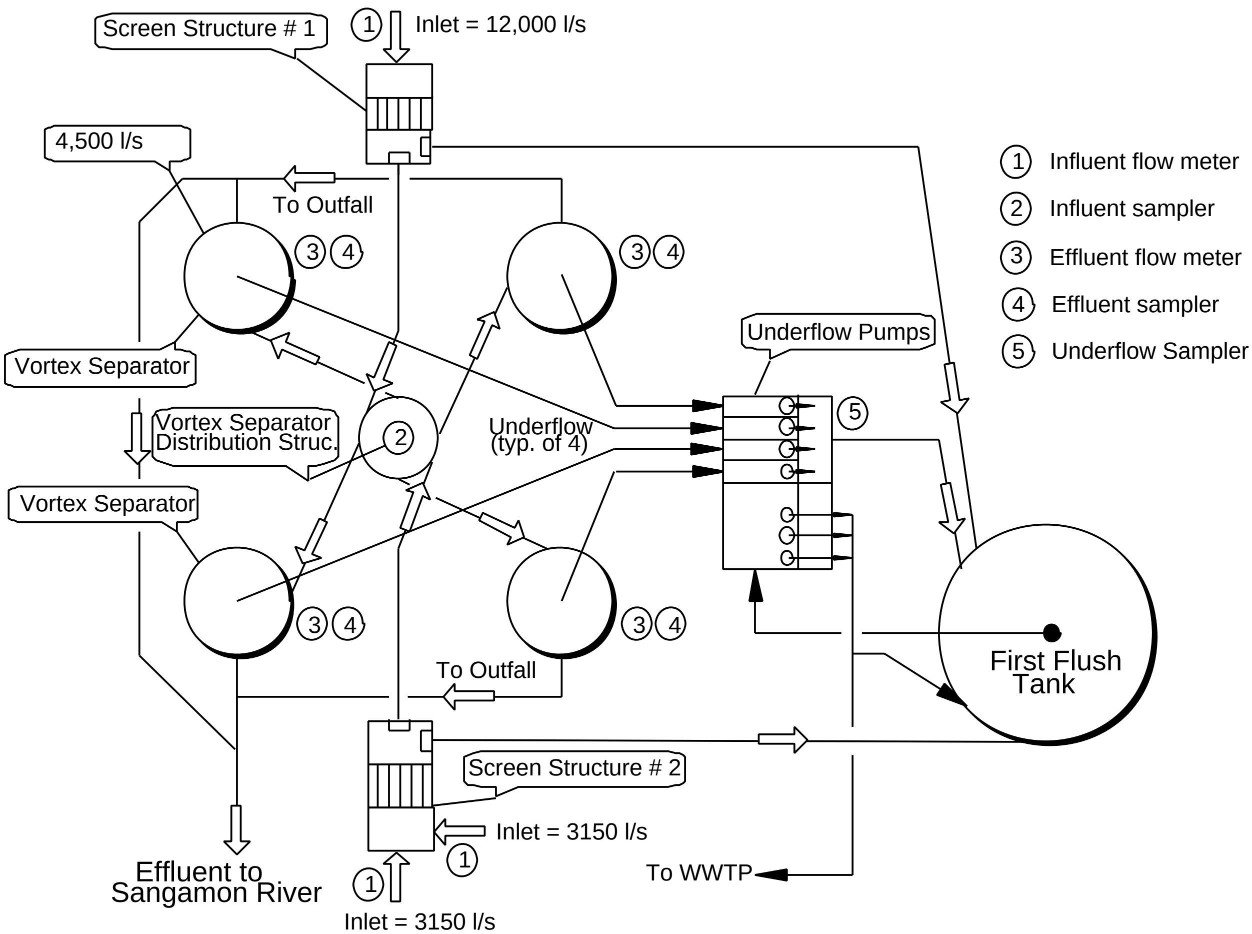
Water cannons typically have a maximum discharge rate of 25 liters/second (400 gpm) each at a working pressure of 2.8 to 5 cm/m^2 (40 to 70 psi) and have a useful working spray radius of 20 to 30 meters (70 to 100 feet). Cannons can rotate 360 degrees horizontally and have about 100 to 120 degrees range of motion in the vertical direction. Water cannons should be provided with shut-off/isolation valves and 2.5 centimeter (1 inch) nozzles. Spray down and cleanup times required per cannon vary depending on the facility, type of solids loading, and time of solids exposure (open tanks). However, cleanup times of 5 to 15 minutes per water cannon are common.

High Pressure Hoses

Most CSO facilities have washdown high pressure hose systems on-site for miscellaneous cleanup operations. This system can often be utilized for secondary cleaning operations by providing hose gates where required. This system requires a piping and valve network, booster pumps and a supply wet well. Hose gate connections are provided throughout the facility to accommodate cleaning operations. If this technology is used as a true secondary flushing system it will require an open tank layout. Hose connections are typically 3 centimeters (1-1/4 inch) and utilize similar water usage and pressure requirements to a water cannon system. Hoses allow the flexibility to move the discharge point around because the hose is not fixed like water cannons.

Novel Approach For Cleaning Circular Tanks

The Lincoln Park facility in Decatur, Illinois consists of two mechanical screening facilities, a 7500 cubic meter (2 million gallons) open circular "first flush" storage tank, a 11 meter (36 feet) diameter vortex flow dividing chamber (two asymmetric flow inputs of 11,000 l/s and 7200 l/s (176,000 gpm and 114,000 gpm) are divided into four 4550 l/s (72,000 gpm)) waste streams, four 13.6 meter (45 feet) diameter vortex solids separators, and a treated effluent to the Sagamon River. Figure 5-8 presents on overall schematic for the facility.



Lincoln Park Facility Monitoring Locations

Figure 5-8. Lincoln Park Schematic

Diverted wet-weather flows (WWF) (two inputs) are first passed through mechanically cleaned, automatically controlled, catenary screens. A manually cleaned bar screen is provided for emergency bypass. Downstream of each screen chamber are two liquid-level actuated, motorized sluice gates directing flow into the "first flush" retention tank. The tank diameter is 36 meters (118 feet) with a side water depth of 8.5 meters (28 feet). The tank is equipped with mixers and aerators and the tank floor slopes to a circular gutter draining to a pumping station. When the tank level rises to a pre-set level, control gates direct any additional inflows to the vortex flow divider with outputs into the four vortex solids separators. Foul underflows from the bottom of the four separators are pumped into the "first flush" tank. The pumping station also dewaters the tank and the separators after an event.

Cleanout of the circular "first flush" tank includes several novel design and operational concepts. First, the two main gravity feeds to the tank are tangentially fed during an event. Secondary flow currents are established moving most of the solids to the center zone of the tank, a common design attribute on hundreds of circular tanks in Germany. After an event the cleaning operation involves two steps. The contents of the tank are kept in motion while being slowly pumped to the interceptor. This circulation feature is accomplished by a feed from the center of the tank with a separate recirculation loop and a tangential return. When the tank is fully drained, no sediment is typically observed from the perimeter tank walls inward for about 4.5 to 6 meters (15 to 20 feet). From there the sediments grade from about 1 cm in depth to about 15 centimeters (6 inches) in the center region of the tank. Two high-pressure water monitors on opposite sides of the tank are then used to cleanse the remaining sediments to the center well in about six minutes.